

FINAL REPORT

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Comparative Study of X-Ray and
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Accomplishments:

The work supported by the grant consisted of two projects. The first project involved making detailed case studies of two flares using SMM data in conjunction with ground based observations. The first flare occurred at 1454 UT on 1989 June 20 and involved the eruption of a prominence near the limb. In the study we used data from many wavelength regimes including the radio, H-alpha, hard X-rays, and soft X-rays. We used a full gyrosynchrotron code to model the apparent presence of a 1.4 GHz source early in the flare that was in the form of a large coronal loop. The model results lead us to conclude that the initial acceleration occurs in small, dense loops which also produced the flare's hard X-ray emission. We also found evidence that a source at 1.4 GHz later in the event was due to second harmonic plasma emission. This source was adjacent to a leg of the prominence and comes from a dense column of material in the magnetic structure supporting the prominence. Finally, we investigated a source of microwaves and soft X-rays, occurring ≈ 10 min after the hard X-ray peak, and calculate a lower limit for the density of the source. This work is reported in the paper by *Kucera et al.*, (1993).

The second flare that was studied occurred at 2156 UT on 1989 June 20 and was observed with the VLA and the Owens Valley Radio Observatory (OVRO) Frequency Agile Array. We have developed a gyrosynchrotron model of the sources at flare peak using a new gyrosynchrotron approximation which is valid at very low harmonics of the gyrofrequency. We found that the accelerated particle densities of the sources decreased much more with radius from the source center than had been supposed in previous work, while the magnetic field varied less. We also used the available data to analyze a highly polarized source which appeared late in the flare. This work is currently being written up.

The second project involved compiling a statistical base for the relative timing of the hard X-ray peak, the turbulent and blue-shift velocities inferred from soft X-ray line emissions observed by SMM and the microwave peak as determined from ground-based observations. This timing was then used to aid the testing of newly developed global models for flares that incorporate the global magnetic topology as well as the electron dynamics that are responsible for the hard X-rays and microwaves. This type of comparative study is important because while magnetic reconnection is believed to be the main driving force for solar flares, there has been to date no way to tie reconnection to the electron dynamics. Present MHD models are subject to another uncertainty : an unidentified anomalous resistivity several orders of magnitude greater than the known plasma resistivity produced by Coulomb collisions has to be assumed to produce reconnection on observed time scales. The modelling supported by this grant are able to overcome these limitations and account for many of the features seen in the statistical study by explicitly incorporating the electron dynamics through particle and modified two-fluid simulations.

These simulations show that the electrons and ions have differential trajectories through the coronal current sheets formed by the shearing and compressive flows driven by the photospheric motions. This differential motion leads to the development of additional plasma

currents that flow around the surface of the current sheet. These surface currents are explicitly neglected in MHD but they are vital to the flare dynamics because they divert current from the coronal current sheet into the chromosphere, producing the needed dissipation to enable reconnection to occur. Because the surface currents are in the plane of magnetic field, electrons in them experience strong acceleration and can account for the observed hard X-ray emissions. Model predictions are compared with observed time profiles of hard X-ray emissions and Doppler shifts seen in soft X-ray line emissions and are able to account for such features as (i) the asymmetry in rise and decay time of the hard X-rays, (ii) the apparent delay between the largest Doppler shifts and the hard X-ray peak, and (iii) the relatively low intensity of the blue-shifted component with respect to the stationary component. The use of particle and fluid simulations is important by providing different, but complementary treatments of the electron acceleration, the global magnetic morphology and the flare current system. This work is reported in the paper by Winglee (1993).

Summary Bibliography:

Thesis Supported

Observations and Analysis of Solar Flares at Radio and Other Wavelengths by T. A. Kucera, Ph. D. Thesis, University of Colorado, Boulder, 1993.

Papers Published

Kucera, T. A., G. A. Dulk, A. L. Kiplinger, R. M. Winglee, T. S. Bastian, and M. Greater 1993, Multiple wavelength observations of an off-limb eruptive solar flare *Astrophys. J.*, **412**, 853.

Submitted Papers

Winglee, R. M., Particle/two-fluid simulations of an eruptive flare: Identifying the field aligned currents responsible for the hard X-rays, *Solar Phys.*, submitted, 1993.